CORRELATION AND STRUCTURE OF THE PRE-CAMBRIAN FORMATIONS OF THE GWINN IRON-BEARING DISTRICT OF MICHIGAN

R. C. ALLEN
Director, Michigan Geological Survey

Published information regarding the geology of the Gwinn district is very meager. In 1873, Major J. B. Brooks published[1] a brief description of the locality now occupied by the Princeton and Stegmiller mines, then known as the S. C. Smith mine, in sections 17, 18, and 20, T. 45, R. 25. In speaking of the occurrence of iron ore there he says: "The geographical position is less remarkable than what might be called its geological isolation, for it appears to be in a small patch of Huronian rocks, in the midst of a great area of barren territory, underlain by the Laurentian and Silurian systems." Brooks observed the black slate adjacent to the ore on the northeast in sections 17 and 18 and in "section 20, west of the river, a talcky schist, holding grains of quartz," but was unable to determine the stratigraphic relation of these rocks to the iron formation.

About ten years later this locality was again examined by Dr. Carl Rominger,[2] who writes as follows: "The Cheshire mine, formerly known as the S. C. Smith mine . . . . is working a strip of slaty and quartzose rock beds, known to extend along the valley of the Escanaba River for a distance of nine miles from the northwest corner of section 19, T. 46, R. 26, to the center of T. 45, R. 25." Rominger describes the rocks shown in the mining pits in sections 18 and 20, T. 45, R. 25, in considerable detail. He recognizes an iron formation underlain and overlain by slate. Owing to his misunderstanding of the structure his succession is reversed.

In 1911 the United States Geological Survey published a brief account of the geology of the Gwinn (Swanzy) district by C. R.

[1] *Michigan Geological Survey*, I, 150–51.

[2] *Ibid.*, V, (1894), Part I, pp. 70–73.

Van Hise and C. K. Leith.[1] These authors had made no detailed survey of this district and attempted merely a summary of the information from other sources available to them at the time their monograph was written. They describe the Gwinn district as a southeastern-pitching synclinorium about two miles long and from one-half to two miles wide, the structure being unknown toward the southeast because of the deep overburden. They correlate the pre-Cambrian sedimentary rocks with the Upper Huronian (Animikee) series and describe them as (1) a basal "quartz slate and quartzite grading down into arkose or decomposed granite" which is overlain by (2) the Michigamme slate carrying the Bijiki iron-bearing formation in "lenses and layers" near its base.

Recent studies by the writer for the Michigan Geological Survey based on field mapping and an examination of the records of several hundred diamond drill holes show clearly that the Gwinn district contains *at least two* unconformable series of sedimentary rocks. It seems probable that the upper series, which will be described as the Princeton series, is equivalent to the Upper Huronian of the Marquette district, that the lower series, which will be described as the Gwinn series, is equivalent to the Middle Huronian of the Marquette district, and that the Lower Huronian series, while not present in the Gwinn synclinorium, is represented by certain fragments of quartzite and cherty slate in the conglomerate at the base of the lower or Gwinn series.

Without the information afforded by records of drill holes and other exploratory operations, any statement of the geology of the Gwinn district would probably be misleading and in any event necessarily fragmentary and incomplete. Outcrops are not plentiful except in certain restricted localities and are limited to the north two-fifths of the district. The records of drill holes, carefully compiled by geologists of the Cleveland Cliffs Iron Co. and the Oliver Iron Mining Co., are the main reliance for mapping the formations. Only a few of the drill samples were seen by the writer, but each of the formations is somewhere exposed either in outcrops or in excavations and was studied on the ground. It will be seen on the

[1] C. R. Van Hise and C. K. Leith, *Monograph 52, U.S. Geological Survey*, pp. 283–86.

TABLE I

TABLE OF CORRELATIONS. MARQUETTE AND GWINN DISTRICTS

	Marquette District—United States Geological Survey	Gwinn District—U.S. Geol. Survey, 1911	Gwinn District—Mich. Geol. Survey, 1913
Quaternary system	Pleistocene series—glacial drift	Pleistocene series—glacial deposits	Pleistocene series—glacial deposits
Ordovician system Cambrian system	Unconformity Upper Cambrian (Potsdam sandstone)	Unconformity Limestone Sandstone	Unconformity Limestone and sandstone
Algonkian system—Keweenawan series	Unconformity Not identified but probably represented by part of intrusives in Upper Huronian	Unconformity	Unconformity Not identified but probably represented by basic dikes which intrude all of the pre-Cambrian formations
Huronian series Upper Huronian	Greenstone intrusives and extrusives Michigamme slate (slate and mica schist) locally represented by Clarksburg (volcanic) formation Bijiki schist (iron-bearing) Goodrich quartzite	Michigamme slate Bijiki iron-bearing member in lenses and layers near base of Michigamme slate Goodrich quartzite. Quartz slate and quartzite grading down into arkose or recomposed granite	Michigamme slate, carrying beds of ferruginous slate and chert, quartzite, and graywacke Conglomerate and graywacke (Goodrich)
Middle Huronian	Unconformity Negaunee formation (iron-bearing) Siamo slate Ajibik quartzite		Unconformity Iron-bearing formation and associated overlying and underlying slate (Negaunee-Siamo) Arkose conglomerate, arkose and quartz-slate conglomerate (Ajibik)

Lower Huronian	Unconformity Wewe slate Kona dolomite Mesnard quartzite		
Archean system Laurentian series Keewatin series	Unconformity Granite, syenite, peridotite Palmer gneiss Kitchi schist and Mona schist	Unconformity Granite	Unconformity Granite and greenstone, mainly granite

accompanying map that information is entirely wanting in some parts of the synclinorium and in other parts is insufficient for accurate mapping. Only a few of the many faults, which certainly occur, particularly in the north end of the district, have been mapped and the exact location and character of even those is not apparent.

The lithology of the various formations will be considered only so far as essential to an understanding of the succession and the correlations, but the discussion necessarily will be more in detail than the account published in *Monograph 52*, to which reference has been made.

Preliminary to the statement of the geology, there is given in parallel columns for comparison the succession and correlation of the United States Geological Survey and of the writer.

LOCATION AND TOPOGRAPHY, ETC.

The Gwinn synclinorium occupies an area about six miles long and from one to two miles wide, mainly in T. 45 N., R. 25 W., but extending a short distance into T. 44 N., R. 25 W. The trend of the major structure is about N. 45° W. or almost exactly parallel to the Republic trough, the southern end of which is 22 miles west and 6 miles north of the north end of the Gwinn fold. Gwinn, the principal village, is 16 miles south of the city of Marquette.

The southeast three-fifths of the Gwinn fold is buried beneath a featureless and almost flat sand plain which extends north and east to the hills of the Marquette range. In the opposite direction the surface is broken and hilly with occasional rock exposures. Granite hills encircle the northwest and north sides of the synclinorium. The district is drained by the Escanaba River, which follows the northeast side of the trough to Gwinn and then turns south across the sand plains. On the plains the water table is within a few feet of the surface and the ore bodies are deeply buried under water-saturated sand and gravel, a condition which is a serious menace to mining operations.

The first shipment of ore was made in 1872 from the Cheshire mine, now known as the Princeton No. 1 pit. About 1902 the Cleveland Cliffs Iron Co. purchased the Princeton (Swanzy,

Cheshire) mine and during the time which has since elapsed has extended its holdings by purchase and lease until it now controls all of the known workable ore bodies with the exception of the Stegmiller, which is mined by the American (Oliver) Mining Co. Since the building of the beautiful and principal village of Gwinn by the Cleveland Cliffs Iron Co. the name of the district has been changed by common usage from Swanzy to Gwinn. There are five producing mines in the district. This number will be six in 1914, and probably eight in 1915. Concrete shafts have been sunk to two additional ore bodies but it is not known when these will be equipped for mining operations.

NOTES ON THE STRUCTURE OF THE GWINN SYNCLINORIUM

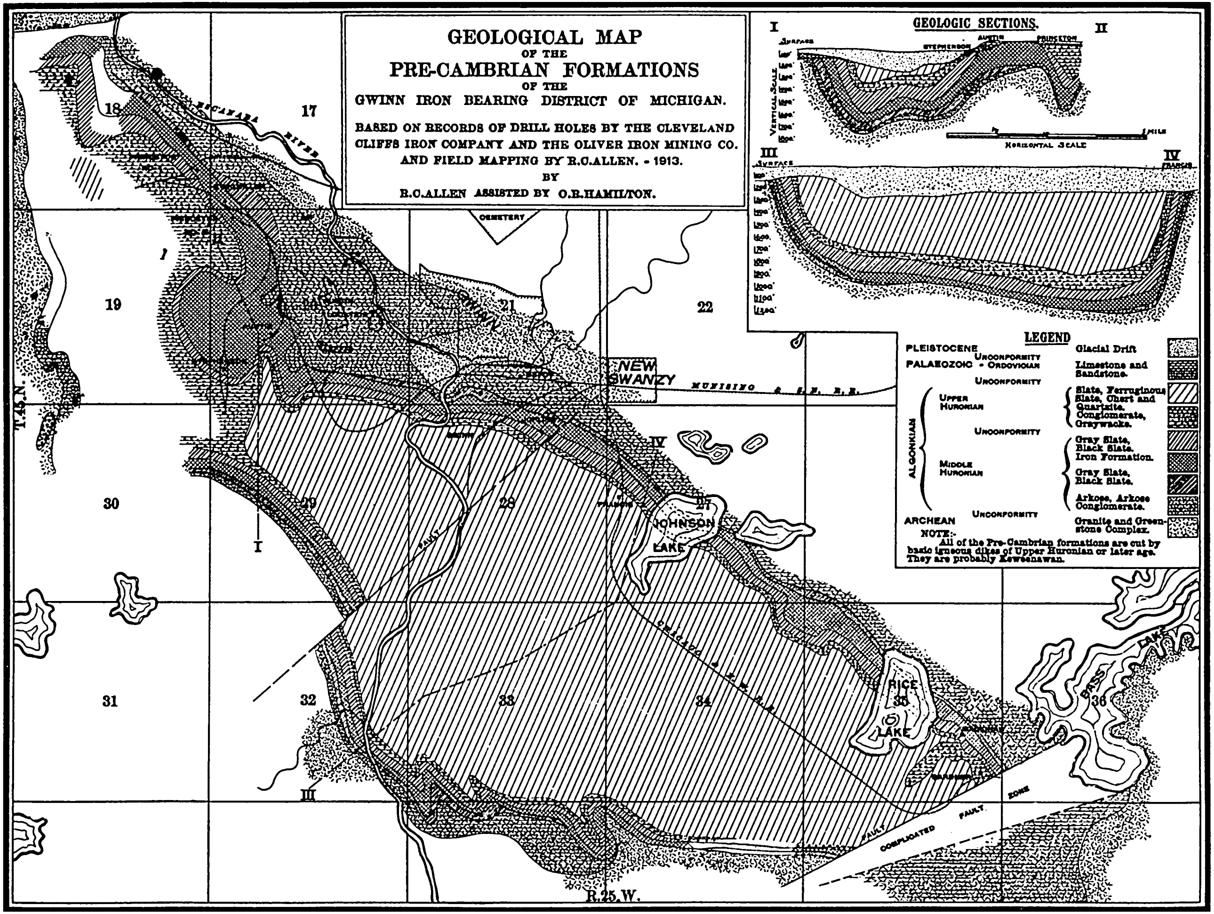
The Gwinn synclinorium contains two unconformable series of sedimentary rocks, having a combined thickness of from 800 to 1,000 ft. Outliers of flat-lying Paleozoic (Cambrian or Ordovician) sandstone and limestone occur throughout this area The pre-Cambrian beds are remnants of formations, originally much more extensive, which have escaped erosion by downfolding or depression in the Archean basement.

The synclinorium is constricted to not more than three-fourths of a mile in width in the vicinity of the N.W. $\frac{1}{4}$ of section 29, T. 45, R. 25. North of the constricted portion, the rocks are folded and faulted in a complex manner but south of it the structure is apparently somewhat less complicated.

The southern three-fifths of the synclinorium is a spoon-shaped basin four miles long with a maximum width of about two miles. The deepest part of the fold is adjacent to the northeast limb where the Archean granite is reached in many drill holes at depths of from 1,000 to 1,200 ft. (see cross-section III–IV). Drilling along the southwest limb indicates a number of sharp drag folds pitching northwest. The folds on the opposite limb are not so sharp and are apparently simple cross-folds. The most prominent one appears in the S.E. $\frac{1}{4}$ of section 35. The synclinorium practically terminates against a faulted zone on the southeast. It is not possible to determine from present information the full extent of this zone nor the character of the faulting. The rocks in the faulted area are largely

slate, chert, conglomerate, and breccia resembling lithologically the succession in the upper or Princeton series, but the regular succession of formations shown on both limbs of the fold terminates abruptly at the line indicated as a fault on the map. Another cross-fault probably trends diagonally northeast through section 28, producing a horizontal displacement of not less than 700 or 800 ft. in the N.E. $\frac{1}{4}$ of section 32 and from 150 to 200 ft. in the N. $\frac{1}{2}$ of the N.W. $\frac{1}{4}$ of section 28. The offset in the latter locality may be explained by folding, but the sharpness of the break in the former locality strongly suggests faulting. In any case, the extension and direction of the fault as indicated on the map is to a considerable degree hypothetical.

Knowledge of the structure of the northeast two-fifths of the Gwinn synclinorium pertains chiefly to the northeast limb. The most conspicuous structural feature of this limb is the broad cross-anticline responsible for the extraordinary surface exposure of the iron formation in the vicinity of the Austin and Stephenson mines, giving rise to two prominent synclines, the northern one carrying the Princeton No. 2 ore body and the southern one the Austin-Stephenson deposit (see cross-section I–II). Northward from Princeton No. 2 mine the east limb is overturned and dips at an angle of about 80° to the northeast, about parallel to a faulted contact with black slate extending from somewhere north of the Old Swanzy pit in the S.W. $\frac{1}{4}$ of the N.E. $\frac{1}{4}$ of section 18 southeast for a distance of probably more than a mile. Where observed in the Swanzy pit and in the Princeton No. 1 pit in the S.E. $\frac{1}{4}$ of section 18, the dip of the fault plane is northeast about 75° or 80°. Both the iron formation and the adjacent slate are intensely sheared along the zone of faulting. The belt of slates adjacent to the fault on the northeast may be stratigraphically either above or below the iron formation so far as the writer has proof. The upper and the lower slate members of the Gwinn series are lithologically very similar. Drill holes and the mine workings show that the iron formation in this vicinity lies directly on the basal arkose member of the Gwinn series with here and there a few feet of black slate lying between them. This makes it very probable that the slate belt northeast of the fault belongs to the upper slate member of


GEOLOGICAL MAP
OF THE
PRE-CAMBRIAN FORMATIONS
OF THE
GWINN IRON BEARING DISTRICT OF MICHIGAN.
BASED ON RECORDS OF DRILL HOLES BY THE CLEVELAND CLIFFS IRON COMPANY AND THE OLIVER IRON MINING CO. AND FIELD MAPPING BY R.C.ALLEN. - 1913.
BY
R.C.ALLEN ASSISTED BY O.R.HAMILTON.
GEOLOGIC SECTIONS.
I
II
III
IV
SURFACE
STEPHENSON
AUSTIN
PRINCETON
VERTICAL SCALE
HORIZONTAL SCALE
1 MILE
LEGEND
PLEISTOCENE
UNCONFORMITY
PALAEOZOIC - ORDOVICIAN
UNCONFORMITY
ALGONKIAN
UPPER HURONIAN
UNCONFORMITY
MIDDLE HURONIAN
ARCHEAN
UNCONFORMITY
Glacial Drift
Limestone and Sandstone.
Slate, Ferruginous Slate, Chert and Quartzite, Conglomerate, Graywacke.
Gray Slate, Black Slate, Iron Formation.
Gray Slate, Black Slate.
Arkose, Arkose Conglomerate.
Granite and Greenstone Complex.
NOTE:-
All of the Pre-Cambrian formations are cut by basic igneous dikes of Upper Huronian or later age. They are probably Keweenawan.
17
18
19
21
22
27
28
29
30
31
32
33
34
35
36
ESCANABA RIVER
CEMETERY
NEW SWANZY
MUNISING & S.E. R.R.
CHICAGO & N.W. R.R.
JOHNSON LAKE
RICE LAKE
BASS LAKE
FAULT
COMPLICATED FAULT ZONE
T.45.N.
R.25.W.

the Gwinn series. North of the middle of section 18, details of the structure are unknown but the distribution of formations indicated by the few exposures and drill holes suggests deformation by both folding and faulting of a complex character.

ARCHEAN SYSTEM

The Archean system comprises both acid and basic plutonic rocks, granite greatly predominating. These rocks inclose the synclinorium on the west, north, and east sides, encircling the north and northwest sides in bold hills and protruding through the drift in low knobs on the east side from New Swanzy northward. Numerous drill holes reach the system after penetrating the overlying sedimentaries within the borders of the synclinorium.

ALGONKIAN SYSTEM

The Algonkian system is represented by two unconformable series of Huronian sedimentary rocks, the Princeton (upper) and the Gwinn (lower) series. Both series are intruded by basic dikes, probably of Keweenawan age. The basal conglomerate of the Gwinn series contains pebbles and bowlders of quartzite, quartz slate, and siliceous, cherty, slightly dolomitic slate derived from a third sedimentary series unconformably below the Gwinn series but not present so far as known in the Gwinn synclinorium.

MIDDLE HURONIAN

GWINN SERIES

There are four members of the Gwinn series, viz., from the base upward, (1) conglomerate and arkose, (2) black slate and gray slate, (3) iron formation, and (4) black slate, gray slate, and graywacke.

1. *Conglomerate-arkose.*—The basal member of the Gwinn series is mainly arkose and arkose conglomerate. It lies on an uneven surface of Archean granite and is reported to occur in isolated patches over a considerable area outside of the Gwinn synclinorium. Within the fold its thickness varies from practically nothing to above 60 ft. The dominant phase of the member is arkose or decomposed granite. It is evident that the arkose has its origin

in the disintegration and subsequent sedimentation of the disintegrated particles of the underlying granite which in many places it resembles so closely that distinction is difficult. There are phases of the arkose in which the feldspar crystals show little perceptible wear, much less the quartz grains. It is particularly difficult to separate from granite in places near the contact where secondary mica has developed and veins of quartz and pegmatite occur like those in the granite. Phases in which there has been perceptible or conspicuous rounding of the quartz and feldspar particles are commonest and these may be either massive or schistose. The schistosity in the arkose is the result of mashing of the feldspars, by which process the quartz grains are generally not greatly affected. Where the arkose is overlain by the iron formation and particularly by iron ore, as in the mines north and west of Gwinn, it is in many places highly decomposed, soft, and iron stained, the feldspars being largely kaolinized.

The conglomerate is much less abundant than the arkose and according to drill records is not present in most localities. Its occurrence seems to be erratic and, curiously enough, where exposed in the S.E. ¼ of the S.W. ¼ of section 19, T. 45, R. 25, it lies some distance above the base of the formation. Drift bowlders of the conglomerate are rather plentiful but the only exposures known to the writer are in the S.W. ¼ of section 19. Here there are 12–15 ft. of it exposed in layers from 1 to 2 ft. thick dipping about 16° E. and striking N. 15° W. At this locality the contact with the granite is about 150 paces west. The matrix of the conglomerate is chiefly arkose but in one exposure it is siliceous, gray slate interbedded with the arkose. The pebbles are up to several inches in diameter and are mainly vein quartz which is abundant in the underlying granite. There are also many fragments of green schist, dense, vitreous, gray quartzite and siliceous, cherty, slightly dolomitic slate of grayish-green color. The composition of the conglomerate may also be studied to advantage on the waste dump of the Gwinn mine in the N.E. ¼ of the N.W. ¼ of section 28 where a bowlder bed was encountered in cutting the pumping-station in the shaft. All of the bowlders are well rounded and vary up to 6 to 7 inches in diameter. The matrix is arkose so decomposed that many

of the bowlders are lying free on the dump. In addition to the rocks represented in the exposures in section 19 there are many bowlders of granite and greenstone.

The origin of the quartzite and slate pebbles is of great interest in its bearing on the correlation of the Gwinn series. Near Little Lake, about five miles east, in a range of hills on the north side of section 19, T. 45, R. 24, there are numerous outcrops of quartzite, quartz slate, and arkose. Van Hise and Leith considered these rocks to be the base (Goodrich quartzite) of the Gwinn series which we have described. In fact, their description seems to apply mainly to these exposures and not to the basal member of the Gwinn series as it actually exists in the Gwinn synclinorium. There is an arkose and arkose conglomerate in these exposures exactly similar even to the pebbles in its associated conglomerate, to the basal member of the Gwinn series. This formation, however, is plainly uncomformably below the quartzites and quartz slates, as proven by the occurrence of a coarse conglomerate at the base of the quartzite carrying numerous bowlders of the arkose some of which are as much as 2 ft. in diameter. The exposures at Little Lake are not in the Gwinn synclinorium but will be described in a later paper. The point is emphasized, however, that the presence of quartzite and cherty, quartz-slate pebbles in the basal member of the Gwinn series proves that there is at least one unconformable series of sediments between the Archean and the Gwinn series. The writer believes that this series is the Lower Huronian as represented in the Marquette district a short distance north.

2. *The lower slate.*—In the southeastern three-fifths of the district a black, graphitic, and gray slate formation intervenes between the basal arkose member and the iron formation. It is less generally present from the Stephenson mine northward, in this area never exceeding a few feet in thickness, but south of the Stephenson mine it varies up to above 60 ft. thick. Were it not for lithologic dissimilarity this slate would be included in the basal member, but inasmuch as it represents a distinct change in conditions of sedimentation and moreover seems to maintain a definite stratigraphic relation to the overlying and underlying formations, it should perhaps be described as a distinct member of the series.

3. *The iron-bearing member.*—Like the other formations in the Gwinn series the iron-bearing member varies markedly in thickness but is nevertheless persistent, occupying a constant and definite stratigraphic position in the series. The description of the occurrence of this member in "lenses and layers" in slate by Van Hise and Leith is misleading in so far as this implies that the member is discontinuous within the synclinorium. The thickness of the iron formation is ordinarily 50–100 ft. with a maximum of probably less than 125 ft. and a minimum of only a few feet as shown in some drill holes toward the center of the basin west of the Princeton and Stegmiller mines. Some sections show a greater thickness than 125 ft., which is accounted for by folding. The formation is thinner and at the same time leaner toward the west side of the synclinorium. All of the known ore bodies are on the east limb of the fold.

The iron formation is mainly banded, ferruginous chert similar to the "soft ore jasper" of the other Michigan ranges. The original or unaltered phase is cherty iron carbonate. North of the Swanzy pit in section 18, the base of the formation, as shown by drilling, seems to be mainly grünerite schist. This part of the district shows evidence of greater deformation by folding and faulting than areas farther south.

The upper part of the iron-bearing member is slaty in many places and the base of the overlying slate is here and there so ferruginous that it is a matter of choice as to whether it should be mapped as slate or iron formation. On the map these phases are included in the overlying slates.

The iron ores are both Bessemer and non-Bessemer grades, the latter greatly predominating, very soft and fine textured in the main and generally high in moisture. A purplish satin luster is a peculiar characteristic of the Gwinn ores. There are some pits in the upper part of the formation west of the Austin mine that show hard jasper and hard, blue hematite. Localization of the ores is largely coincident with synclinal troughs and faulted zones but is not limited to these structures. An inclined position of the iron formation between the overlying slate and underlying slate or arkose satisfies the structural requirements for ore concentration.

4. *The upper slate.*—The upper slate member is from 30 to 100 ft. thick. It is unconformably overlain by the basal conglomerate of the Princeton series. Its relation to the underlying iron-bearing member is largely gradational. It comprises an interbedded series of black slate, gray slate, and dark graywacke-quartzite. The black graphitic phase is more commonly directly above the iron formation than the gray slate, and the graywacke-quartzite phase seems to be in upper and middle horizons.

PRINCETON SERIES

The Princeton series consists of an interbedded series of slates, ferruginous slates, and cherts, quartzites, ferruginous quartzites, and graywacke with a basal conglomerate. The series is 400–500 ft. thick. Probably the entire thickness is not represented in the Gwinn fold. It is rarely seen in outcrops but it has been penetrated by numerous drill holes and some open pits. For the purpose of this article the interesting member is the basal conglomerate.

The basal conglomerate varies from 30 to 50 ft. to more than 100 ft. in thickness. Nearly all of the many drill holes which cross its horizon show its presence but here and there it is represented by a coarse graywacke. So far as known, the only exposures are in the S.E. $\frac{1}{4}$ of the N.E. $\frac{1}{4}$ of section 18, T. 45, R. 25, where a number of exposures occur on a low brush-covered ridge. Adjacent to them on the east the upper slate member of the Gwinn series is exposed in pits. The strike of the conglomerate is N. 70° W. and the dip 80° N.

The matrix of the conglomerate is coarse, dark graywacke-quartzite, the pebbles are chert and siliceous black slate, quartz, and arkose, derived from the underlying Gwinn series, and quartzite. The matrix carries a good deal of disseminated ferruginous material and some very small fragments of iron ore. There are also a good many small irregular cavities in the rock which are lined with hematite and limonite produced by weathering-out of iron-bearing fragments of some kind. The largest chert fragments are two to three inches long and one-half to an inch wide. All of them show wear by attrition, the smaller ones being generally lens shaped.

So far as can be ascertained, the Princeton and Gwinn series are structurally almost accordant. The strike of the conglomerate

where exposed in section 18 indicates discordance in trend with the Gwinn series, but too little is known of the structure in that vicinity to place any importance on this observation.

KEWEENAWAN SERIES (?)

Basic dikes have been cut in a few drill holes and may be observed in section 20, T. 45, R. 25, cutting the basal arkose member of the Gwinn series. These dikes intrude both the Princeton and the Gwinn series. They are younger than Palaeozoic and older than the Princeton series. Their age is therefore probably Keweenawan.

PALEOZOIC

Isolated remnants of limestone and sandstone of Cambrian or Ordovician age, or possibly both, occur throughout the district. Some of these are in excess of 50 ft. thick. No fossils or other means of determining the exact age of these outliers is available at the present time.

CORRELATION OF THE GWINN AND THE PRINCETON SERIES

It has been shown that the pre-Cambrian sedimentary rocks of the Gwinn synclinorium consist of two unconformable series. The unconformity between them is marked by a basal conglomerate the position, extent, and thickness of which imply an important erosion interval which intervened between the periods of deposition of the two series.

Concerning the respective ages of these two series, it may be said that probably no geologist familiar with the pre-Cambrian formations of the Lake Superior region would correlate the Gwinn (lower) series with the Lower Huronian. It contains an important iron formation associated with graphitic slates, an assemblage of rocks not known in the Lower Huronian. Moreover, the basal conglomerate carries fragments of quartzite and quartz slate dissimilar to any known Archean sediments in Michigan but exactly similar to certain Lower Huronian rocks in the adjacent Marquette district. This evidence considered in connection with the unconformity separating the Princeton and the Gwinn series is a sufficient basis for the correlation suggested in this paper, but an additional consideration tending to show that the Gwinn series is

Middle Huronian appears in the absence from its basal conglomerate of jasper fragments from the Negaunee fo:mation so strongly developed in the adjacent Marquette district.

Escape from the correlations suggested in this paper involves a disregard or subordination of the importance of the unconformity separating the Gwinn and the Princeton series. There is no certain evidence in this synclinorium of great structural discordance between these two series but it may be and probably is as great as that separating the Upper Huronian and the Middle Huronian series of the Marquette district. Great structural discordance could hardly be expected inasmuch as the main deformation took place after the deposition of the Princeton series. Some structural discordance is implied in the consideration that although the upper slate member of the Gwinn series was probably not cut through in this district, there was sufficient erosion in adjacent territory to uncover the different members of the entire Gwinn series prior to the deposition of the basal conglomerate of the Princeton series.